Energy Security Implications of Introducing Renewable Portfolio Standard in Indonesia

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***Abstract*—An AIM/Enduse model has been developed to examine the implications of considering renewable portfolio standard (RPS) in Indonesia on energy security. Three levels of RPS are considered in this study, i.e., 15%, 25%, and 35%, while the planning horizon of analysis is from 2005 to 2035. The energy security is measured based on the diversification of energy use in the total primary energy supply (TPES). The diversification of energy use is measured by using Shannon-Weiner Index (SWI). The results show that the SWI would increase with the introduction of RPS. The SWI at the base case during the planning horizon would be 1.325, and would increase to 1.443, 1.553, and 1.621 if RPS of 15%, 25%, and 35% are considered respectively. The Shannon-Weiner Indices increase due to an increased share of renewable energy, such as wind, pv, biomass, and nuclear to the total energy use in the power sector.**

***Index Terms*—AIM/Enduse, renewable portfolio standard, renewable energy, energy security**

I. Introduction

RENEWABLE energy is known as low carbon fuel which emits nearly zero CO_2 emissions. Renewable energy is now one of the options to slow down the production of CO_2 emission. Renewable energy is also used to increase the energy security of a country because this energy can be used to diversify the energy use and reducing energy import dependency. Like other developing countries, the share of renewable energy to the total energy use in Indonesia is very low, i.e., less than 1% [1]. Indonesia is now targeting the share of the renewable energy use more than 5% by 2025. There are several policies to promote renewable energy, one of them is renewable portfolio standard. A Renewable Portfolio Standard (RPS) is a requirement on electric utilities and other electric suppliers to supply a minimum percentage or amount of their load with eligible sources of renewable energy. The resources may include such as wind, solar, biomass, and others. If RPS is introduced in power sector development in Indonesia, some questions might be raised, such as (i) how would RPS affect the energy security of the country? and (ii) how would RPS affect the CO_2 emissions and local pollutant emissions?

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There is a substantial body of literature on considering RPS in power system planning (see e.g., [2-3]); however, their focus was on industrialized countries only. [4] analyzed the implications of considering RPS in power sector development, but they did not discuss the effect of RPS on energy security.

The present study will analyze the implications of introducing renewable portfolio standard on energy security and environment in Indonesia during 2005-2035. This paper is organized as follows. The brief explanation of the model used in this study is presented in the next section, followed by the energy resources in Indonesia, data and data sources and the scenarios description used in the study. The implications of considering renewable portfolio standard are examined in the subsequent sections. Finally, major findings are presented.

II. Model Framework

This study uses the Asia-Pacific Integrated model (AIM)/ Enduse to analyze the implications of considering RPS on energy security and environment. AIM/Enduse model is one of the models under the AIM family, and it is a bottom up linear programming optimization sub-model in AIM. The Asia-Pacific Integrated model (AIM) has been developed by the National Institute for Environmental studies (NIES) of Japan as a first and only integrated assessment model focusing on Asia which was used to evaluate policy options on sustainable development particularly in the Asia-Pacific region ([5]). The general concept of the AIM/Enduse model is an end-use driven scenario analysis which includes the end-use technology, energy and environmental database to estimate the energy consumption, in both for combustion and non-combustion operations of technologies and environmental emissions quantities. This model is based on a partial equilibrium framework. As seen in Fig. 1, The AIM/Enduse model is disaggregated into four levels of tree structure: primary energy, secondary energy, demand service and service demand. The model accounts for the flow of energy resources from resource extraction to end-use thought energy conversion refinery process considering energy characteristics of the technologies involved in each level. The model will select the technology, which is based on the annualized capital cost and running cost of technologies including energy cost in a given year. The objective function of the model is to minimize the total cost (TC) which comprises of three main components. These components are, (i) total annualized fixed cost which is used for evaluating recruitment of devices in a given year, (ii) total running cost, which comprises cost of energy used by devices and cost of operation and maintenance of device and (iii) total cost of emission tax in that year including energy tax and emission tax. The total cost is optimized according to six basic constraints which include service demand, device share ratio, operation capacity, device stock exchange, energy supply constraints and emissions. The emissions constraint sets limitations of some of the pollutants. For a given service, its demand must be met by the quantity of service output supplied by all devices in the ratio of service output of a device to total service output of all devices must not exceed its upper limit or maximum share. The operating quantity of each device should not exceed the assigned value of the operating rate. A certain stock of previous year's combination of devices will retire at the end of its life, with its quantity reducing linearly during its lifetime. These devices can be replaced in the current year by combining with another set of devices recruited in a given year. The stock that is replaced in the current year should not exceed the stock that is passed on from the previous year. The energy supply constraint refers to the quantity of an energy kind in a sector, cannot exceed its maximum allowable limit. The emissions constraint will limit the emissions of a gas from a sector to a specified value. In addition, to these inequality constraints there are also equality constraints for internal energy balance and stock balance. The stock of devices in the current year is equal to the sum of the stock of devices transferred form the previous year, quantity of the combination recruited in the current year and the net stock of other combinations of devices that are exchanged in the current year. The internal energy balance is for all energy kinds to be supplied as internal services from the energy conversion and supply sectors. For more information regarding the formulation of the AIM/Enduse model see [5].

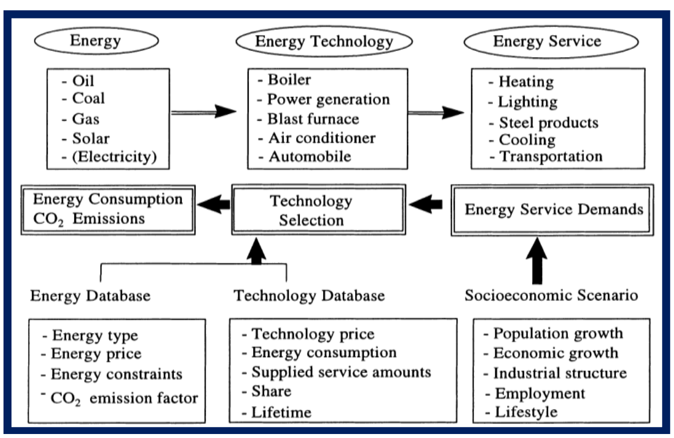

Fig. 1. Structure of the AIM/Enduse model (Sources [5])

III. Energy Resources in Indonesia

The total primary energy supply (TPES) in Indonesia increased from 12.9 Mtoe in 1992 to 190.6 Mtoe in 2007 with an average annual growth rate of 3.6% [6]. The TPES in Indonesia varies from fossil energy to renewable energy. The role of fossil energy (such as coal, oil and gas) is very significant at the present time in Indonesia. Of the energy use in TPES in year 2007, the share of oil is the highest, i.e. about 36.6%, and then followed by coal and gas as much 34.4% and 25.9% respectively [1]. The fossil energy is mostly used in power-, industrial- and transport-sectors. In addition to fossil energy, renewable energy is also used in various sectors in Indonesia. Unlike the fossil energy, the renewable energy is not widely used Indonesia. The renewable energy is mostly used in the power sector, such as geothermal and hydro.

The diversification of energy use in TPES, which is shown by Shannon-Weiner index (SWI), shows an increasing figure during 1992-2007. In year 2007, the SWI of Indonesia was 1.19, which is higher than the SWIs at the previous years. This shows that the energy security had increased during 1992-2007 (see Fig. 2).

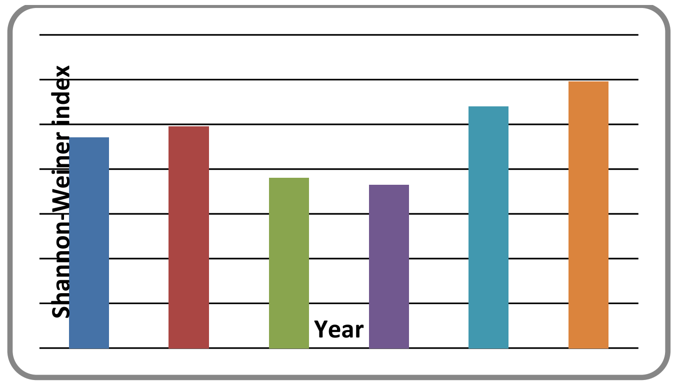

Fig. 2: The Shannon-Weiner Index (SWI) of energy use of TPES in Indonesia during 1992-2007

IV. Data and Data Sources

The input data for the AIM/Enduse model are taken from various sources and also by using some forecasting methodology.

- Agricultural data for tilling, irrigation and milling is taken from [7]. The service demand for the future years (ASD_t) are estimated by applying linear regression analysis as shown in the following equation:

$$ASD_t = a + b\,GDP_t + c\,POP_t \quad (1)$$

  where: ASD_t = agricultural service demand in year t; GDP_t = GDP in year t; POP_t = population in year t; a, b, c = parameters. The parameters a, b and c are obtained from the similar regression model based on the historical data of ASD_t, GDP_t and POP_t.
- Commercial data for air conditioning, refrigerator, lighting, air conditioning, elevator, thermal use was taken from some surveys. The forecast for the future is estimated by using the floor space area.
- Residential data for lighting, TV, refrigerator, fan, cooking, iron, air conditioning was taken from some surveys. The forecast for the future was done by using the forecast of number of population in the future.
- Transport data was taken from [8]. From this source, we can obtain passenger-km in year 2005. The forecast in the future was done by applying linear regression analysis as shown in the following equation:

$$PASS_t = a + b\,GDP_t + c\,POP_t \quad (2)$$

  where: $PASS_t$ = passenger-km in year t; GDP_t = GDP in year t; POP_t = population in year t; a, b, c = parameters. The parameters a, b and c are obtained from the similar regression model based on the historical data of $PASS_t$, GDP_t and POP_t.

- Industrial data was taken mostly from [9]. From here production data for cement, iron and steel, etc could be obtained. The future service demand was done by considering value added in each industry.

$$SD_{i,t} = (SD_{i,o}/VA_{i,o})\ VA_{i,t} \quad (3)$$

where: $SD_{i,t}$ = service demand of sector i in year t; $SD_{i,o}$ = service demand of sector i in year 2005; $VA_{i,t}$ = value added of sector i in year t; $VA_{i,o}$ = value added of sector i in year 2005.

V. Scenarios Description

There are four scenarios are considered in this study, they are a base case scenario and three renewable portfolio standard scenarios. The base case scenario is a business as usual scenario, that is a scenario which considers the current social-economic data and there is no policy intervention from the government to promote renewable energy. The renewable portfolio standard scenarios are scenarios which maintain the minimum level of the renewable energy use. There are three minimum level of renewable energy use are considered i.e., 15%, 25%, and 35% (hereafter the scenarios are called RPS15, RPS25, and RPS35). In this study, the renewable portfolio standards are only applied in the power sector only. So, RPS15 means that the electricity generated from the renewable energy should not be less than 15% of the total electricity generation of the base case. The minimum levels of the total electricity generated from the renewable energy in the renewable portfolio standard scenarios are higher than the total electricity generated from the renewable energy use in the base case. The planning horizon of the study is considered from 2005 as the base year until 2035, while the renewable portfolio scenarios are considered during 2013-2035.

VI. Results and Discussions

The renewable portfolio standard would affect the the energy use in the TPES. The diversification of the energy use would increase with the increase of the level of the renewable portfolio standard. In this study, the diversification of energy use is measured with the Shannon-Weiner Index (SWI). The SWI at the base case during 2005-2035 is 1.325. If RPS of 15% (or RPS15) is introduced, the SWI would be 1.443. If the RPS is increased to 25% and 35% (i.e., RPS25 and RPS35), the SWI would be 1.553 and 1. 621 respectively.

Introducing renewable portfolio standard would decrease the total CO_2 emissions in the whole economy. The results show that the CO_2 emissions in the whole economy would decrease by 1.5%, 3.4%, and 5.6% at RPS15, RPS25, and RPS35 respectively. The reduction of CO_2 emissions is mainly due to the reduction of natural gas use which is replaced by renewable energy. The renewable portfolio standard would also affect the the total emission of local pollutant emissions such as SO_2 and NO_x. The reduction of SO_2 emissions during the planning horizon at RPS15, RPS25, and RPS35 would be 0.9%, 1.3%, and 2.1% respectively. Similar to SO_2, the NO_x emissions would also decrease with the introduction of renewable portfolio standard. The reducion of NO_x emissions at RPS15, RPS25, and RPS35 during the planning horizon would be 1.1%, 2.5%, and 3.3% respectively.

Introducing renewable portfolio standard in the electricity sector would also affect the CO_2 intensity of the energy use. The CO_2 intensity of the energy use in year 2035 at the base case would be 52 kg/GJ. The CO_2 intensity would decrease with the introduction of renewable portfolio standard. At RPS15, RPS25, and RPS35, the CO_2 intensity of energy use would be 51 kg/GJ, 47 kg/GJ, and 44 kg/GJ respectively at the same year.

Introducing renewable portfolio standard would decrease the total primary energy use (TPES). The results of the study shows that the TPES would decrease by 0.06%, 0.14% and 0.21% if RPS15, RPS25, and RS35 are introduced respectively.

In the electricity sector, introducing renewable portfolio standard would increase the thermal generation efficiency, i.e., from 32.3% at the base case to 41.3% at RPS30%. The increase of the thermal generation efficiency is due to the increase of the electricity generated from efficient biomass based power plants, such as BIGCC. As a result, the total energy use in the electricity sector would decrease with the introduction of renewable portfolio standard.

Other implications of introducing renewable portfolio standard are the improvement of the power system reliability which is measured by loss of load probability (LOLP). The LOLP at the base case would be 0.1785, and would decrease to 0.1673 at RPS30. The capacity factor would decrease from 62.3% at the base case to 60.9% at the highest renewable portfolio standard (RPS30). The capacity factor is decreasing is due to the reduction of electricity generated from less efficient power plant technologies.

VII. Conclusions

This study has developed an AIM/Enduse model to analyze the effects of considering renewable portfolio standard in the Indonesian power sector on energy security. Other co-benefits of the renewable portfolio standard are also examined in this study. The planning horizon of the study is from 2005 to 2035, while the renewable portfolio standard is considered starting form year 2013 until 2035. There are three levels of renewable portfolio standard are considered in the study, i.e., 15%, 25%, and 35%. In this study, the energy security is measured with Shannon-Weiner Index (SWI). This index shows the diversification of the energy use in the total primary energy supply (TPES). The results of this study show that the energy security would increase with the introduction of renewable portfolio standard. The SWI would increase from 1.325 at the base case to 1.443, 1.553, and 1.621 if renewable portfolio standards of 15%, 25%, and 35% are introduced. The results also show that the CO_2 emissions would decrease by 1.5%, 3.4%, and 5.6% from the base case if renewable portfolio standard of 15%, 10%, and 25% are introduced respectively. The SO_2 and NO_x emissions would also decrease with the introduction of renewable portfolio standard. The SO_2 emissions would decrease 0.9%, 1.3%, and 2.1% from the base case if 15%, 25%, and 35% of renewable portfolio standards are considered respectively; while the NO_x emissions would decrerase 1.1%, 2.5%, and 3.3% from the base case if renewable port folio standards of 15%, 25%, and 35% are considered respectively.

VIII. ACKNOWLEDGMENT

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